Estimates of Growth of *Cryptochiton stelleri* (Middendorff, 1846) in Oregon

BY

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DURING 1964 AND 1965 PALMER (1968), in connection with a study on the interrelation between the polynoid worm *Arctonoe vittata* (Grube, 1855) and its hosts, marked and measured the size of a number of *Cryptochiton stelleri* (Middendorff, 1846). The marking method proved feasible. Although tags were lost at a considerable rate, they seemed not to be injurious in any major way; some remained for periods of a year or more. Moreover, the initial data of Palmer, although difficult to interpret because precise measurements on living animals are well-nigh impossible, suggested that additional work would prove worth-while. Thus Frank instituted a marking program in June 1968, from which further recaptures are available. Joseph Standaert, an undergraduate research participant sponsored by N. S. F., helped with the marking. During subsequent summers, David Policansky and Carolyn Cross searched for marked animals. This analysis of growth was partly supported by N. S. F. Grant GB 5032 to Frank.

ANIMALS AND THEIR TREATMENT

In different parts of the study, *Cryptochiton* were marked and replaced in several areas within 8 km south of the mouth of Coos Bay, Oregon. The majority of the recaptures are from Cape Arago. Most animals were recaptured within 20 m of the point of release (where this was known precisely enough), even after 2 years. Although Palmer sampled populations by diving, in water to 10 m depth, the other data are almost entirely from the intertidal zone and to ½ m below spring low tides.

Marking was with a loop of 8 - 10 lb. test monofilament nylon to which colored glass beads were attached for identification. The loop was sewn through one side of the girdle so that it penetrated the animal for a distance of about 3 cm. A complete loop was formed by knots coated with methacrylate plastic. Marking was done both in the field and at the Oregon Institute of Marine Biology in nearby Charleston.

Because of considerable changes in dimensions when the animals bend, and the difficulty in getting them to attain a standard relaxed condition after handling, length measurements are virtually useless. Measurements of circumference with a tape are somewhat better but still yield highly variable results. Weight is the only feasible means of estimating size. However, weight is affected by the precision of the balance, the water adhering to the surface of the animal, the amount of food in the gut, and the variable amount of gonadal material as well as by somatic tissues and shell. Palmer tried weighing animals in water and in air, and finally settled on air weights as more repeatable than other measures. A minimum estimate of the amount of variation introduced by imprecision of the balance combined with change in gut contents is available from pairs of weights obtained at succeeding recaptures not more than 4 days apart for 32 animals. The standard deviation of the difference in pairs of weights was 32.6 g. So high a value is, of course, not conducive to precision of the growth analysis. It is, however, an inescapable element in it.

We have useful data from 228 animals recaptured a total of 398 times. There was an interval of at least 3 months between initial marking and release, and first recapture; and between all subsequent recaptures. No estimates of mortality are possible because tag losses were high and variable. In one area where more than 300 animals were released in the summer of 1968, it was apparent by fall that tags were disappearing at an unusually high rate. In this area sea urchins (*Strongylocentrotus* spp). were abundant. It is an index to their activities that on every visit during the fall monofilament tags chewed by them could be found on about 20% of the marked chitons. By spring of the next year virtually all tags had disappeared.

We have one-year records for 71 chitons, two-year records for 9 chitons, and 3-year records for 3 chitons. A year, for our purposes, is from 350 to 380 days.

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Besides recapturing marked animals, we made general observations on movements and feeding rates. Spawning among a group of individuals was observed once in the field. Individuals were dissected once a month for checks on feeding and reproduction. An insufficient number of animals were sacrificed, however, to yield statistical information comparable to that of TUCKER & GIESE (1962) on spawning cycles 6°50′ lat. farther south.

RESULTS

The MACGINITIES (1968) and TUCKER & GIESE (1962) have remarked on the rarity of small animals in the field. Although a special search for young chitons was made and more than 20 (weighing 50g or less) were marked, we were unable to find any of these small chitons at the end of a year. Table 1 indicates the pattern of growth as observed. The data from recaptures for periods shorter than a year, among them some recaptures of small animals, are dealt with below. From the data, the normal pattern of animal growth, with a maximal increment for intermediate weights, seems to hold. Most individuals encountered in the field range from 20 - 30cm in length when relaxed and weigh between 500 and 800g. Although the MacGinities estimate age (from growth lines on the shell plates) of such an average animal at roughly 12 years, this estimate looks on the high side on the basis of our data, which are for a different area. Incidentally, we were unable to find clear indications of growth lines numbering more than 7 in shell plates of animals of any size. From the growth data, best estimates for ages of animals weighing 400g is probably 5 years; for 800g, 8 years; and for 1 200g, 16 years. However, this is interpreting the data rather more precisely than they deserve. Certainly *Cryptochiton* is relatively long-lived, at least off the Oregon coast, with a maximum longevity of more than 20 years. Some further indications validating the growth data in Table 1 and extending them come from the few 2- and 3-year records we have, and from shorter period recaptures of small individuals. It is probably best to recount the 2- and 3-year growth records individually.

Table 1

Growth as measured by annual change in weight of *Cryptochiton stelleri* of various sizes

Weight range (g)	Avg. change in weight per year	S D	N	S E
300 - 399	93	--	1	--
400 - 499	90.8	81.6	10	25.8
500 - 599	136.2	99.6	17	24.2
600 - 699	114.9	76.7	12	22.2
700 - 799	155.0	99.0	9	33.0
800 - 899	49.8	58.1	16	14.5
900 - 999	58.1	70.0	8	24.7
1 000 - 1 099	46.6	75.8	5	33.8
1 100 - 1 199	--	--	-	--
1 200 - 1 299	59	5.7	2	4.0

Animal No. 577 weighed 450g on August 8, 1968. It weighed 530g on June 1, and 525g on August 13, 1969. It was last found on July 19, 1970, when it still weighed 525g.

Animal No. 583, with an initial weight of 760g in August 1968, had lost 60g by the next January, and had regained its original weight a year after marking; by July 1970, this animal weighed 925g.

Animal No. 594, with an initial weight of 580g in August 1968, fluctuated within 30g of this weight during 3 recaptures; at its 4th recapture in June 1970 it weighed 600g.

Animal No. 595, with an initial weight of 820g on August 8, 1968, gained 140g the first year, but weighed only 950 g almost 2 years later on July 17, 1970.

Animal No. 596, with an initial weight of 885g in August 1968, weighed 1 010g the next May, only 950g in July 1969, and was down to 900g by that September. By July 1970, its recorded weight was 1 115g.

Animal No. 598, with an initial weight of 720g in August 1968, weighed 930g that November, and 800g in January 1969; the following August its weight was 975g. Almost a year later, in July 1970, it weighed 1 025g.

Animal No. 479 weighed 635g on July 12, 1968; 850g on July 19, 1969; 875g on the 28th of the same month. The identical weight, 875g, was recorded twice more, the last time on July 18, 1970.

Animal No. 700 weighed 575g in August 1968. By November its weight was 670g, but a month later it was down to 535g. Four weights obtained during the summer of 1969 ranged from 630 to 720g. In May 1970, this individual weighed 725g. On August 21, 1970 it had increased to 800g.

Animal No. 253, with an initial weight of 1 120g in July 1968, weighed only 100g more in August 1971. Its lowest weight was 980g in January 1969 and its greatest weight was 1 250g in August 1970.

Animal No. 257, with an initial weight of 635g in June 1968, increased to 1 090g in June 1969. A month later its weight dropped to 975g. In July 1971 it weighed 1 100g.

Animal No. 727 weighed 620g in August 1968. In May 1969 it had increased to 730g and a year later, August 1970, to 875g. Its final weight showed a decline to 790g in July 1971.

Only 7 individuals with an initial weight less than 200g were recaptured more than 3 months after marking. These small animals occur in crevices where they easily escape detection, although even here they are not abundant. (The argument that they really are common but extremely hard to find is intrinsically incontrovertible, but, from what searches we have made, seems unlikely.) Data from these recaptures are given in Table 2.

Table 2

Growth data for small *Cryptochiton stelleri*

Identification Number	Initial Weight (g)	Initial Date	Final Weight (g)	Final Date
RBBR	50	24 July 1964	115	15 May 1965
575	50	8 August 1968	75	16 January 1969
553	100	27 July 1968	170	16 January 1969
RRRG	121	27 July 1964	171	18 December 1964
BBRR	123	10 July 1964	188	15 May 1965
722	130	9 August 1968	130	3 May 1969
GGYR	153	27 July 1964	194	20 November 1964

During the field observations, seasonal differences in the animals' behavior were evident. From late October to April even the large chitons were less conspicuous. Then they usually could be found adhering tightly to the substratum or to large, loose boulders. Individuals were not seen actively feeding during this time, whereas in later spring and in summer feeding was often observed. Changes in weight tend to support the idea that *Cryptochiton* here fast during the winter, probably because of a relative paucity of larger algae but perhaps also for other reasons. (These may include turbulence, salinity and turbidity of the coastal water.) Such a cessation of feeding seems not unusual, and apparently also occurs in *Tegula funebralis* (A. Adams, 1855) (see Frank, 1965). Evidence for fasting comes from dissections of *Cryptochiton* in December 1968, and January, February and March 1969, when guts were lacking visible food material; in summer the foregut was often stuffed with millimeter-sized and larger pieces of algae. We do not know whether feeding is so restricted that a real loss in tissue weight occurs. Total weight does decrease at this time, as attested to by numerous short-term weight changes, of which, at this time of year only, the majority are negative (Table 3). The data we have from weighing, dissection, and observations of spawning, indicate that shedding of gametes occurs in June or early July. This may be compared with the observation of Tucker & Giese (1962), who place spawning between March and May among animals occurring some 750km farther to the south.

Table 3

Percentage of positive short-term (less than 3 months) weight changes in *Cryptochiton stelleri* at different times of year

Month of recapture	Number of recaptures	Percentage showing weight gain
December	33	36.4
January	29	41.4
May	78	80.8
June	24	70.8
July	35	71.4

DISCUSSION

Habitat differences of *Cryptochiton* living in different latitudes raise some interesting questions. Many, though not the majority, of individuals along the Oregon coast range into the low intertidal zone. This is not true farther south, where subtidally the animals are probably equally abundant. What behavioral elements are involved and whether there is a genetic basis for the difference are not known. It is conceivable that the intertidal animals are those displaced from otherwise more favorable subtidal areas by intraspecific competition. However, there is no evidence whatever for such a supposition. Unfortunately, our data provide insufficient information to make a useful test of the hypothesis that growth rate among intertidal and subtidal animals is the same. The amount of individual variation observed is too great, and it obscures small, systematic differences that may exist. There is the further complication that it is possible and likely that localized populations may have different growth rates. Certainly, size distributions in locales 100 m or more apart differ. Such differences may result from long-term movements or from differences in growth rate. More thorough examinations of differences in size distribution over an area encompassing perhaps as much as 1 km^2 may be required if any real attempt is to be made to trace such differences to even proximate causes.

It is necessary to emphasize that the growth rates observed in Oregon may be exceedingly poor estimates for other areas. This is not the appropriate place for a lengthy discussion of the question of temperature compensation. It would be of considerable interest, however, to have data comparable to ours for, say, the central California coast. Judging from results for *Tegula funebralis* (Frank, in MS), growth rates twice those we have observed would not be inconsistent there. If this should prove true, life spans in the southern part of the range of this chiton quite possibly may not exceed 10 years. Equally interesting would be an examination of growth among these animals farther north.

In the light of our inability to detect unambiguous growth lines corresponding to those seen by the MacGinities (1968), it seems doubtful that comparisons of shell plates from different areas will be sufficiently useful to give clearcut answers to such questions. However, this certainly seems the first place to look.

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